

ENERGY ABSORBING SYSTEM

This application is a continuation of co-pending, commonly assigned U.S. Patent Application No. 09/268,572 filed on March 15, 1999. This application claims the benefit 5 of German patent application no. 198 13 998.5 filed on March 28, 1998.

BACKGROUND OF THE INVENTION

The invention relates to a process for the production of structural elements absorbing energy with defined 10 characteristics, these elements being produced as shaped members (also referred to herein as "hollow bodies") from a matrix material and a reinforcing material embedded therein.

Shaped members of this type are known, for example, from DE-B 37 44 349.

15 The use of such shaped members as structural elements is likewise known, for example, in EP-A-0 130 009 or DE-A-196 27 061.

Proceeding on the basis of the known solutions, the object underlying the invention is to provide a process for 20 the production of an energy-absorbing structural element, with which an energy absorption with defined characteristics may be realized in a simple manner.

SUMMARY OF THE INVENTION

This object is accomplished in accordance with the invention, in a process of the type described at the outset, in that in different areas of the shaped member layers of the reinforcing material are arranged so as to extend in relation thereto in a defined manner and be arranged with a number differing in a defined manner, and that the reinforcing material for the entire shaped member is wound in a single winding procedure to form the shaped member.

The advantage of the inventive process is to be seen in the fact that, on the one hand, defined energy-absorbing characteristics of the structural element can be produced and that, on the other hand, such a complex structural element can be produced very easily, namely by means of a single winding procedure.

A shaped member of this type may be produced in various ways, for example, by means of a winding procedure with multiple supply of pieces of flat material.

However, the inventive process may be carried out particularly advantageously when the reinforcing material is supplied to the winding procedure in the form of a single piece of flat material which is contoured in such a manner that the required defined orientation of the layers and the number of layers differing in a defined manner are present in the shaped member after the winding procedure.

This has the great advantage that the required orientation and, in particular, the different number of layers in different areas are defined by the contour of the piece of flat material such that no attention need be paid to

the differences in the individual areas during the winding procedure.

Furthermore, this process has the advantage that the number of layers present in the individual areas may also be
5 altered in a simple manner, namely simply by altering the contour of the piece of flat material.

With respect to the contouring of the individual pieces of flat material for achieving defined characteristics of the energy absorption, no further details have so far been given.
10 This contouring may, in principle, be brought about in any optional manner.

A basic pattern for such contoured pieces of flat material does, however, provide for the piece of flat material to have a section with a maximum width transverse to
15 the winding direction and at least one section with a lesser width transverse to the winding direction. A contour of this type can, for example, be similar to a wedge or similar to a step and creates the possibility of generating with the section of a maximum width transverse to the winding
20 direction layers which extend essentially over the entire length of the shaped member in the direction of the winding axis and then additional layers which serve, for example, as reinforcement layers so that areas with a greater number of layers and areas with a lesser number of layers result and
25 when these break varying forces also occur and thus energy is absorbed to varying degrees.

The contouring of the piece of flat material can take place at different points of time. For example, one embodiment of the inventive process advantageously provides
30 for the piece of flat material to be contoured in the section influencing the areas having a number of layers differing in

a defined manner during the course of the supply of a web of flat material to the winding procedure; this means that, for example, the piece of flat material results during cutting out of the contour from the web of flat material during
5 supply thereof to the winding procedure.

Another alternative solution provides for the piece of flat material to be contoured in the section influencing the areas having a number of layers differing in a defined manner prior to the supply to the winding procedure; this means that
10 finished, contoured pieces of flat material are supplied individually one after the other to the various winding procedures.

The contouring of the pieces of flat material, for example, proceeding from a web of flat material can be
15 brought about in a simple manner in that the piece of flat material is contoured by means of a cutting procedure.

This cutting procedure can be a cutting procedure of such a type that the contour to be cut out is followed with a cutting knife.

20 It is, however, also possible to carry out the cutting procedure in such a manner that at least connected parts of the contour are cut out with a punch knife.

The inventive process may be carried out particularly economically when the reinforcing material is wound such that
25 a maximum extension of the contoured piece of flat material in the direction of a winding axis corresponds to the maximum extension of the shaped member in the direction of the winding axis; this means that the supply direction of the piece of flat material may essentially form a right angle
30 with the winding axis and thus a particularly rapid supply of

the piece of flat material to the winding procedure is possible.

The winding of the shaped member may be designed to be particularly economic when several pieces of flat material
5 are supplied to the winding procedure in parallel and thus several shaped members can be wound from the pieces of flat material at the same time. This is of considerable advantage, in particular, for a mass production or large-scale production.

10 The supply of several pieces of flat material to the winding procedure may be of a particularly favorable design when the several pieces of flat material can be supplied to the winding procedure as a connected arrangement of pieces of flat material since, as a result, a parallel supply may be
15 ensured in a simple manner due to the connection of the various pieces of flat material and thus the device for the supply of the several pieces of flat material can also be of as simple a design as possible.

The several pieces of flat material could, in principle,
20 be designed to be connected in all the sections. It is particularly favorable for the separation of the resulting shaped members when the several pieces of flat material are connected in the region of the sections which increase the number of layers in all the areas of the shaped member in an
25 equal manner.

In the case, in particular, of pieces of flat material which have a section of maximum width, it is provided for the pieces of flat material to be connected in the section of maximum width. In this respect, the pieces of flat material
30 can, for example, be designed to be connected in the entire section of maximum width. It is, however, also possible for

the pieces of flat material to be connected merely via webs so that the later shaped members are more easy to separate.

The embedding of the reinforcing material in the matrix material can be brought about in the most varied of ways. It
5 would, for example, be conceivable to wind the reinforcing material first of all and subsequently apply the matrix material after the winding. This would, however, impair the speed during the production of the inventive shaped members. For this reason, a particularly advantageous embodiment
10 provides for the reinforcing material to be impregnated with the matrix material prior to the winding of the reinforcing material to form the shaped member and so during the winding not only is the reinforcing material shaped into the shaped member but the matrix material is supplied at the same time.

15 During the supply of reinforcing material impregnated with matrix material it is particularly favorable when the winding is carried out with a flowable or saturatable matrix material so that the winding of the reinforcing material to form the shaped member can be used at the same time for the
20 purpose of embedding the reinforcing material with the various layers completely in the entire matrix material since the flowing matrix material allows the desired embedding of the reinforcing material in it.

For example, this would be possible in that the matrix
25 material is supplied as a flowable or saturatable material with the reinforcing material; this does, however, have disadvantages for the handling of the reinforcing material during the supply to the winding.

For this reason, it is preferably provided for the
30 matrix material to become saturatable during the winding, i.e. either becomes more liquid in the case of a duroplast as

a result of heating or in the case of a thermoplastic material is melted to the melting point as a result of heating.

In the case of a thermoplastic material, it is provided
5 for the matrix material to be kept at melting temperature during the entire winding.

This would be possible, on the one hand, in that the matrix material is heated to melting temperature prior to the winding, for example, during the time, during which it is
10 supplied to the reinforcing material.

A particularly advantageous solution does, however, avoid the heating up of the matrix material to melting temperature prior to the winding and rather provides for the matrix material to be heated to melting temperature during
15 the winding.

One possibility is heating via an external supply of heat such as, for example, hot air, electromagnetic radiation or gas flame.

As an alternative or in addition it is provided for the
20 matrix material to be heated to melting temperature by means of a heated winding tube and kept at this temperature.

The winding procedure may be carried out particularly quickly when the winding tubes are heated prior to the winding to the melting temperature of the matrix material or
25 above this so that the matrix material is melted immediately upon contact of the reinforcing material with the impregnated matrix material.

In this respect, it is favorably provided for the winding tubes to be heated prior to their insertion into the
30 winding device so that the reinforcing material can be wound with matrix material immediately after insertion of a winding

tube into the winding device without having to wait a heating-up time.

Alternatively to providing a thermoplastic matrix material, another embodiment provides for the matrix material 5 to be a duroplast.

In this case, it is preferably provided for the matrix material to be heated during the winding only to such an extent that this is liquid to an adequate degree during the winding of the reinforcing material.

10 In the case of a duroplast, it is preferably provided for the matrix material to be hardened in the shaped member after the winding and so an adequate hardening time for the matrix material must be provided after the winding.

15 This may be carried out particularly favorably when the matrix material is hardened with a shaped member seated on the winding tube so that the winding tube determines the desired shape during the hardening of the matrix material.

20 In order to achieve sufficiently high transit times, it is preferably provided for the winding tubes wound with the shaped members to be combined during the hardening of the matrix material to form groups of winding tubes which pass together through the hardening phase.

25 With all the possible variations of the inventive process, it is preferably provided for the shaped members to be cooled when seated on the winding tubes and thus the shaped members are not removed from the winding tubes until after complete hardening or solidification of the matrix material.

30 This removal of the shaped members from the winding tubes may be carried out, in particular, in that the shaped members are withdrawn from the winding tubes.

When carrying out the embodiments of the inventive process described thus far, with which several pieces of flat material are designed to be connected, the separation of the shaped members produced therefrom by way of winding can be brought about in the most varied of ways. According to one variation it would be conceivable to separate the shaped members prior to the hardening, for example, on the winding tube.

Alternatively thereto, it is provided for the shaped members to be separated after the hardening.

This may be carried out particularly favorably when the connected shaped members are separated after the withdrawal from the winding tubes since, in this case, a simple separation, for example, by way of sawing may be realized.

The present invention also provides an energy absorbing system, which employs an energy absorbing structural element produced in accordance with the processes described above.

In an example embodiment of such an energy absorbing system, a fitting is provided having a crack inducing surface extending radially outward in relation to an axis. An energy absorbing element formed by a hollow body is also provided. The hollow body extends along the axis and has a first end adapted to interact with the crack inducing surface of the fitting so as to radially spread the hollow body, thereby forming cracks in the hollow body in response to forces applied in a direction substantially parallel to the axis which forces push the crack inducing surface against the first end. The hollow body may have layers of reinforcing flat material embedded in a matrix material and may comprise a single winding of the flat material about the axis. A

number of layers of the reinforcing flat material in the hollow body may be different in different areas of the hollow body.

The layers of reinforcing flat material may extend in
5 the hollow body in a defined manner to cause: (i) the forces to be absorbed by the hollow body without folding; and (ii) the layers of reinforcing flat material to receive cracks which begin at the first end and expand through the different areas of the hollow body in the direction substantially
10 parallel to the axis.

The surface of the fitting may be toroidal in shape. A crack triggering element may be arranged on one of the fitting or the hollow body end. The crack triggering element may comprise a chamfer at the first end of the hollow body
15 adapted to interact with the crack inducing surface. The crack triggering element may comprise slits in the first end of the hollow body.

The reinforcing flat material may comprise a single piece of flat material. The single piece of flat material may
20 have a section with a maximum width in a direction parallel to the axis and at least one section with a lesser width in the direction parallel to the axis.

Sections of the flat material may be contoured to provide the different areas having the different number of
25 layers during supplying the flat material to a mandrel to form the hollow body. The piece of flat material may be contoured by means of a cutting procedure.

In an alternative example embodiment, sections of the piece of flat material may be contoured to provide the
30 different areas having the different number of layers prior to supplying the flat material to a mandrel to form the

hollow body. The piece of flat material may be contoured by means of a cutting procedure.

A maximum extension of a contoured piece of flat material in a direction parallel to the axis may correspond 5 to a maximum extension of the hollow body in the direction parallel to the axis.

In one example embodiment, multiple pieces of flat material may be supplied to a winding procedure in parallel to form the hollow body. The multiple pieces of flat material 10 may be supplied to the winding procedure as a connected arrangement of pieces of flat material in which the pieces of flat material are arranged in a sequence extending in a direction parallel to the axis. The multiple pieces of flat material may be connected in a section which increases the 15 number of layers in all the areas of the hollow body in an equal manner. For example, the pieces of flat material may be connected in a section with maximum width.

In a furether example embodiment of the present invention, the reinforcing flat material may be impregnated 20 with the matrix material prior to a winding of the reinforcing flat material to form the hollow body.

The winding of the reinforcing flat material may be carried out with one of a liquid or a liquifiable matrix material. The matrix material may be liquefied during the winding. The 25 matrix material may be kept at a melting temperature during the entire winding of the reinforcing flat material. The matrix material may be heated to the melting temperature during the winding of the reinforcing flat material.

The matrix material may be heated to the melting 30 temperature by means of a mandrel which is heated and kept at the melting temperature. The mandrel may be heated to the

melting temperature of the matrix material prior to the winding. The mandrel may be heated to the melting temperature of the matrix material prior to insertion into a winding device.

5 The matrix material may be heated to such an extent that it is adequately liquefied during the winding of the reinforcing flat material.

10 The matrix material may be hardened in the hollow body following the winding. The matrix material may be hardened with the hollow body seated on a winding tube.

The matrix material may comprise one of a thermoplastic material or a duroplast material.

15 The fitting may comprise a cylindrical guide section having a casing surface which abuts an inner surface of the hollow body at the first hollow body end and a channel section extending annularly around the axis and having a base surface bordering the casing surface and extending radially outward in relation to the axis. The channel section may be toroidal in shape.

20 The energy absorbing system may further comprise a second fitting having a contact surface transverse to the axis and adapted to support the hollow body at a second end thereof.

25 The energy absorbing system may further comprise securing means for securing the second end of the hollow body to the second fitting. The second end of the hollow body may be adapted to absorb the forces without folding and to transfer these forces to the second fitting so that the cracks are induced in the first end of the hollow body and 30 extend along the axis toward the second end.

Additional features and advantages of the inventive solution are the subject matter of the following illustrations of several embodiments of inventive shaped members and several embodiments of processes for the winding
5 of such inventive shaped members.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will hereinafter be described in conjunction with the appended drawing figures, wherein like reference numerals denote like elements, and:

- 5 Figure 1 shows a longitudinal section through a first embodiment of an inventive shaped member, used in connection fittings which cause an energy-absorbing destruction of the shaped member when a force is applied thereto;
- 10 Figure 2 shows an illustration of the relationships between a piece of flat material for the production of the shaped member in accordance with the first embodiment, the shaped member and the energy absorption characteristics with the piece of flat material not yet wound for the production of the shaped member in Figure 2a
- 15 the shaped member wound from a piece of flat material in Figure 2b and
- 20 the energy absorption characteristics in Figure 2c;

Figure 3 shows an illustration similar to Figure 2 of a second embodiment of an inventive shaped member with:

5 the piece of flat material not yet wound for the production of this shaped member in

Figure 3a,

the wound piece of flat material in
Figure 3b and

10 the energy absorption characteristics in
Figure 3c;

Figure 4 shows an illustration similar to Figure 2 of a third embodiment of an inventive shaped member with

15 the piece of flat material not yet wound in Figure 4a;

the piece of flat material wound to form the shaped member in Figure 4b and

the energy absorption characteristics in Figure 4c;

20 Figure 5 shows a schematic illustration of the first embodiment of an inventive process for the winding of an inventive shaped member;

- Figure 6 shows a view of a device for the impregnation of the reinforcing material with matrix material in the direction of the arrow A in Figure 5;
- 5 Figure 7 shows a schematic illustration of a variation of the first embodiment of the inventive process in Figure 5;
- Figure 8 shows an illustration of a second embodiment of an inventive process;
- 10 Figure 9 shows an illustration of a third embodiment of the inventive process; and
- Figure 10 shows an illustration of division of a web of flat material with several consecutive arrangements of pieces of flat material.

DETAILED DESCRIPTION

The ensuing detailed description provides exemplary embodiments only, and is not intended to limit the scope, applicability, or configuration of the invention. Rather, the
5 ensuing detailed description of the exemplary embodiments will provide those skilled in the art with an enabling description for implementing an embodiment of the invention. It should be understood that various changes may be made in the function and arrangement of elements without departing
10 from the spirit and scope of the invention as set forth in the appended claims.

One embodiment of an inventive energy-absorbing structural element 10 illustrated in Figure 1 is built up, for example, as a shaped member (hollow body) which is
15 circular-cylindrical in relation to a central axis 12 and has several layers 16a to 16h of a flat material forming a reinforcing material, wherein, for example, only three layers 16a to 16c of flat material are provided in a first area 18a extending in the direction of the central axis 12 whereas
20 five layers 16a to 16e of flat material are provided in a second area 18b and in a third area 18c of the shaped member 14 a total of eight layers 16a to 16h of the flat material are provided. In a final area 18d, the individual layers of the flat material extend in the direction of the axis 12 over
25 varying lengths, wherein the lowermost layer 16a extends in the direction of the central axis as far as an end edge 20 of the shaped member and the following layers are each set back in relation to the lowermost layer 16a such that, altogether, a chamfer 22 of the shaped member 14 is formed in the region
30 of a first end 24 of the shaped member, wherein a surface 26

of the chamfer 22 represents a conical surface with respect to the central axis 12.

A second end 28 of the shaped member 14, which is located opposite the first end 24 and from which the first 5 area 18a proceeds, has an end face 30 which is located in a plane 32 extending at right angles to the axis 12.

Such an energy-absorbing structural element 10 may be arranged, for example, between two connection fittings 34 and 36. The first connection fitting 34 triggering the energy 10 absorption has a guide section 38 which has a cylindrical shape and a casing surface 40 circular-cylindrical in relation to the axis 12. The guide section 38 engages in an interior 42 of the shaped member 14 and thereby abuts on an inner surface 44 of the shaped member 14 which limits the 15 interior and is cylindrical in relation to the axis 12 so that the shaped member is guided in the direction of the axis 12.

The first connection fitting 34 has, in addition and following the guide section 38, a channel 50 which extends 20 annularly around the axis 12 and has, in particular, a base surface 52 which borders on the casing surface 40, extends radially outwards in relation to the axis 12 and is, for example, toroidal in shape. If the shaped member 14 is pushed onto the guide section 38 with the first end 24, 25 namely to such an extent that an end edge 20 is located close to a beginning of the toroidal surface 52 of the channel 50 and the chamfer 22 adjoins this, the first end 24 of the shaped member 14 provided with the chamfer 22 is spread in a radial direction in relation to the axis 12 during a relative 30 displacement of the first connection fitting 34 in the direction of the arrow 54 so that, in the region of the

chamfer 22, the layers 16a to 16h of the reinforcing material receive cracks extending in the direction of the axis 12 and thus the shaped member 14 is destroyed, for example, fractured in the region of the first end 24 and thus expands 5 in a radial direction. This fracturing in a radial direction due to expansion or spreading of the first end 24 of the shaped member 14 then absorbs the desired energy, wherein the fracturing can continue beyond the area 18d, the area 18c and the area 18b as far as the area 18a.

10 In order to support the shaped member 14 at the second end 28 when the connection fitting 34 is moved in the direction of the arrow 54, the second connection fitting 36 is provided with a contact surface 60 which is parallel to the plane 32 and on which the end face 30 of the second end 15 28 is supported. The shaped member 14 is preferably also secured in the region of the second end 28 by means of a guide ring 62 abutting on the inner surface 44.

The stability of the shaped member 14 in the first area 18a must thereby be such that this area is in a position to 20 absorb the forces acting in the direction of the axis 12 without folding and to transfer these to the connection fitting 36 with the end face 30.

Such a shaped member 14 illustrated in Figure 1 may be produced in accordance with the invention, as illustrated in 25 Figure 2, from a reinforcing material which comprises a piece 72 of flat material consisting of reinforcing fibers and provided with a defined outer contour 70 by way of cutting and which has a maximum width B in the direction transverse to a main direction 73 of the orientation of the reinforcing fibers and approximately parallel to them longitudinal edges 30 74, 76, which corresponds approximately to the extension of

the shaped member 14 from the end edge 20 as far as the end face 30.

Furthermore, the second longitudinal edge 76 extends in the form of a continuous longitudinal edge from a later, 5 interior transverse edge 78 of the winding, which extends essentially over the entire length of the shaped member 14 from the end edge 20 as far as the end face 30, as far as a later, exterior transverse edge 88 of the winding.

The first longitudinal edge 74 of the piece 72 of flat 10 material extends from the later, interior transverse edge 78 of the winding as far as a step edge 80 which extends transversely to the main direction 73 to a longitudinal edge 82 which is set back and parallel to the longitudinal edge 74 and is offset in the direction of the longitudinal edge 76 in 15 relation to the longitudinal edge 74 and, for its part, again extends as far as a step edge 84 extending transversely to the main direction 73 and proceeding from which an additional longitudinal edge 86 which is set back and parallel to the longitudinal edge 74 extends as far as the later, exterior 20 transverse edge 88 of the winding which is located opposite the later, interior transverse edge 78 of the winding.

In contrast to the longitudinal edges 74, 82 and 86, the longitudinal edge 76 extends without any step from the transverse edge 78 as far as the transverse edge 88.

25 The longitudinal edge 76 deviates slightly from a fictitious transverse edge 90 extending parallel to the longitudinal edges 74, 82 and 86 and, proceeding from the later, interior transverse edge 78 of the winding, is placed with increasing extension in the direction of the later, 30 exterior transverse edge 88 of the winding such that it has

an increasing distance from the fictitious longitudinal edge 90 (Figure 2a).

If the piece 72 of flat material is now aligned such that the transverse edge 78 extends parallel to the axis 12 and is wound onto a winding tube rotating about the axis 12 and not illustrated in the drawings, the section having the maximum width B between the transverse edge 78 and the step edge 80 results in the first three layers 16a to 16c, which are illustrated in Figure 1 and extend essentially over the entire length of the shaped member 14 in the direction of the axis 12. The step edge 80 thereby defines as a result of its extension in the direction of the axis 12 the extension of the area 18a in the direction of the axis 12 which has, for example, three layers 16a to 16c of the reinforcing material 70.

A further section of the piece 72 of flat material between the step edge 80 and the step edge 84 forms on the first three layers 16a to c two additional layers 16d and 16e in the areas 18b and 18c which, with respect to their extension in the direction of the axis 12, correspond to the extension of the step edge 84 and the transverse edge 88 in the direction of the axis 12. The step edge 84 thereby defines as a result of its extension in the direction of the axis 12 the extension of the area 18b in this direction. Finally, a section of the piece 72 of flat material between the step edge 84 and the transverse edge 88 essentially forms the section 18c, comprising altogether eight layers 16a to 16h, wherein the extension of the section 18c in the direction of the axis 12 corresponds to the extension of the transverse edge 88 in this direction.

In order to obtain, in addition, at the first end 24 the chamfer illustrated in Figure 1, the longitudinal edge 76 does not extend parallel to the fictitious longitudinal edge 90 but has an increasing distance from this fictitious
5 longitudinal edge 90 with increasing distance from the transverse edge 78 of the piece 72 of flat material and so with increasing winding of the layers 16a to 16h in the region of the first end 24 the chamfer 22 illustrated in Figure 1 is formed.

10 When the longitudinal edge 76 forms the chamfer 22 and the longitudinal edge 74 the end face 30, such a shaped member 14 illustrated again schematically in Figure 2b increasingly absorbs energy over a first path section W1 in accordance with the characteristics illustrated in Figure 2c
15 during the movement of the connection fitting 34 in the direction of the arrow 54, wherein this corresponds to the breaking of the reinforcing fibers of the shaped member 14, which extend in the piece 72 of flat material in the main direction 73 and in the shaped member 14 in azimuthal
20 direction in relation to the axis 12, close to the first end 24 in the region of the chamfer 22.

Subsequently, the greatest absorption of energy takes place over a path section W2, which corresponds approximately to the extension of the transverse edge 88 in the direction
25 of the axis 12 and thus to the third area 18c, as a result of further fracturing of the shaped member 14 over the section 18c since the reinforcing fibers extending in azimuthal direction in the area 18c, which has the most layers 16a to h, break. Thereafter, a further fracturing in the area 18b
30 follows over the path section W3, for which purpose less energy is required due to the smaller number of layers 16

and, finally, over the path section W4 a breaking possibly in
the region of the first section 18a which absorbs the least
energy on account of the smallest number of layers 16. A
degressive characteristic of the absorbed energy can thus be
5 achieved altogether, wherein the characteristics can be
predetermined in a defined manner by the dimensioning of the
edges of the outer contour 70 of the piece 72 of flat
material to be wound.

The characteristics of the absorbed energy may be
10 varied, as illustrated, for example, in Figure 3 on the basis
of a second embodiment of an inventive shaped member 14', due
to alteration of the outer contour 70 into the outer contour
70' of the piece 72 of flat material.

If the outer contour 70' is, for example, determined by
15 the longitudinal edge 76 and the additional longitudinal
edges 74 and 82', wherein the longitudinal edge 74 merges
into the longitudinal edge 82 via a step edge 80' extending
at an angle, the arrangement of the individual layers 16 may
be altered by altering the measurements of the transverse
20 edge 88 and the step edges 80 and the number of layers 16 by
altering the longitudinal measurements of the individual
longitudinal edges 74, 76, 82', (Figure 3a) in the shaped
member 14', (Figure 3b) and thus the course of the absorbed
energy according to Figure 3c, as well.

25 Similarly, as illustrated in Figure 4, a degressive
course of the absorbed energy may be reversed in that the
same piece 72 of flat material with the outer contour 70 is
used as in the first embodiment but in a reverse arrangement
so that, in this case, the first end 24 is formed by the
30 longitudinal edge 74 while the second end 28 is formed by the
longitudinal edge 76.

The production of inventive shaped members 14 may be brought about in the most varied of ways. A first embodiment illustrated in Figure 5 provides for a web 100 of flat material, comprising the reinforcing material and an impregnation thereof with, for example, a thermoplastic matrix material, to be supplied from a supply device 104 in a supply direction 106 to a winding device 108 with a winding tube 110 driven for rotation about the axis 12 in order to produce the pieces 72 of flat material, wherein the web 100 of flat material has transversely to the supply direction 106 a width B which corresponds exactly to the width B of the piece 72 of flat material.

During the supply of the web 100 of flat material to the winding tube 110, the contour 70 of the piece of flat material is cut with a cutting device 112, illustrated merely by way of a cutting knife, and so, in the end, the piece 72 of flat material is wound on the winding tube 110 with the desired contour. In order to thereby obtain an intimate bonding between the reinforcing material and the matrix material, the winding tubes 110 are preheated in a preheating device 114 arranged next to the winding device 108 prior to the winding of the piece 72 of flat material impregnated with matrix material and so during the winding of the piece 72 of flat material provided with matrix material onto the winding tube 110 the matrix material is liquefied and melted, as a result of which a secure embedding of the piece 74 of flat material serving as reinforcing material in the molten matrix is brought about.

Following the winding of the shaped member 14, this is cooled together with the winding tube 110 in a cooling device 116 with, for example, a cooling path so that the molten matrix material again has the possibility of hardening.

5 Subsequently, the finished shaped member 15 is withdrawn from the winding tube 110 in a withdrawal device 118, and this winding tube 110 is conveyed via a transport path 120 again to the heating device 114 for the purpose of heating up.

10 The winding tubes 110 are preferably arranged not only in the winding device 108, the heating device 114, the cooling device 116 but also in the withdrawal device 118 so as to each be coaxial to the axis 12 and are merely displaced along the axis in order to move them from one device to the
15 other.

The provision of the web 100 of flat material with matrix material has not so far been described in detail. For example, as illustrated in Figures 5 and 6, an impregnating device 130 is provided which supplies thermoplastic films to
20 the web 100 of flat material consisting of reinforcing material from both sides likewise in the form of a respective web 132 of material, these films being rolled onto respectively opposite sides of the web 100 of flat material in a rolling device 134 by means of two rollers 136 and 138
25 in order to obtain the web 100 of flat material provided with matrix material for supplying to the winding device 108.

In a variation of the inventive process according to Figures 5 and 6, illustrated in Figure 7, the production of the pieces 72 of flat material impregnated with matrix material takes place separately and also the cutting thereof so that the pieces 72 of flat material which are already cut

and impregnated with matrix material are placed on a transport device 150 for them and transported by the transport device 150 to the winding device 108 in order to likewise be wound onto the winding tubes 110 preheated in the
5 heating device 114.

In a further embodiment of the inventive process, illustrated in Figure 8, pieces 72' of flat material are wound onto the winding tubes 110, wherein, in this case, the pieces 72' of flat material are impregnated with a
10 duroplastic matrix material which hardens automatically.

In this case, the heating device 114 serves merely for the preliminary heating of the winding tubes 110 in order to accelerate the duroplastic hardening process.

In a hardening device 160 following the winding device
15 108, the duroplastic material of the shaped members 14 already wound is hardened, wherein for reasons of saving on time several winding tubes 110 wound with shaped members 14 are preferably combined to form a group 162 of winding tubes which passes through the hardening device 160 and is
20 subsequently cooled altogether in a cooling device 164. This means that the relatively long periods of time for the hardening and cooling of the shaped members 14 provided with duroplastic matrix material is utilized in an optimum manner and so a high rate of production of shaped members 14 is
25 nevertheless possible.

The cooling device 164 is followed by the withdrawal device 118, in which the finished shaped members 14 are withdrawn from the winding tubes 110 and the winding tubes 110 are again supplied to the heating device 114 via the
30 transport path 120.

In addition, a machining device may be provided after the withdrawal device and this makes possible, for example, a machining of the chamfer 22 or instead of the chamfer 22 in the area 18d the introduction of so-called triggering slits 5 extending in the direction of the axis 12.

In a third embodiment of the inventive process, illustrated in Figure 9, several pieces 72a to f of flat material are arranged next to one another such that they are connected in the region of their longitudinal edges 74, 76 10 extending approximately parallel to one another, wherein the longitudinal edge 76a of the preceding piece 72a of flat material is connected, for example, to the longitudinal edge 74b of the subsequent piece 72b of flat material.

The pieces 72 of flat material are connected, in 15 particular, in their sections 180, in which the longitudinal edges 74, 76 extend parallel to one another and with which no alteration in individual areas of the shaped member with respect to the number of the layers is possible. On the other hand, no connection of the pieces of flat material is 20 preferably provided in the region of the sections 182 which, when wound to form the shaped member, result in a different number of layers in different areas of the shaped member.

Such an arrangement 184 of pieces of flat material formed from connected pieces 72a to 72f of flat material may 25 be supplied as a whole to the winding tube 110' in the winding direction 106, this tube having an extension in the direction of the axis 12 which allows all the pieces 72a to 72f of flat material to be wound at the same time.

Thus, a plurality of shaped members 10, which are all 30 connected to one another, results on the winding tube 110'.

The wound shaped members may then be hardened together on this winding tube 110' and also be withdrawn together from the winding tube 110' so that after the withdrawal of the entirety of shaped members, formed from the pieces 72a to 72f of flat material, a separation thereof, for example, by sawing can be carried out in the region of abutting longitudinal edges 74, 76.

In a particularly advantageous solution, illustrated in Figure 10, it is illustrated in addition how several arrangements 184a to c of pieces of flat material may be produced from a single web 186 of material, the width of which corresponds to the width of the pieces 72a to 72f of flat material located next to one another, without a single cut, wherein the sections 182 of the individual pieces of flat material, which contribute to areas with different numbers of layers of the shaped member when they follow one another, must, however, have a complementary shape.

Furthermore, different types of shaped members result during such a performance of the inventive process, namely those, in which the sections 182 are located radially inwards, and those, in which the sections 182 are located outwards.

It should now be appreciated that the present invention provides advantageous processes for producing energy absorbing structural elements, as well as advantageous energy absorbing systems.

Although the invention has been described in connection with various illustrated embodiments, numerous modifications and adaptations may be made thereto without departing from the spirit and scope of the invention as set forth in the claims.